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## Des ription

This inventi n relates to a m thod of calibrating x-ray tub filament currents. This invention als relates to an x-ray tube system.

Each model and type of x-ray tube conventionally has a published set of filament emission curves or tables. These curve sets or tables commonly take the form of a graph of filament current against tube current or mA for each of plurality of fixed tube voltages or kV. For example, the curve set might include curves for each of three or four tube voltages between 50 kV and 150 kV.

In an x-ray device, the x-ray tube is commonly operated for a selected duration at a selected tube current and voltage combination. This generates a corresponding amount of x-rays of the appropriate energy to penetrate the patient or subject and properly expose photographic film or provide appropriate x-ray flux for other x-ray detection equipment. Generally, the tube voltage across the anode and cathode is readily set. The tube current is controlled by adjusting the current flowing through the cathode filament. Increasing the filament current increases electron emission from the cathode which increases the tube current or electron flow between the cathode and anode. By referring to the filament emission curve set, the filament current required to produce a selected tube current at a selected tube voltage is readily determined.

Heretofore, x-ray equipment has been calibrated with data taken from the filament emission curves. Most commonly, the filament emission curves were used to set the filament current that would be supplied for each combination of x-ray tube currents and voltages that could be selected. To be sure that these were accurate, an initial calibration process was frequently conducted. Either manually or automatically, exposures were taken with each of a plurality of the selected x-ray tube current and voltage parameters. The actual tube current produced was compared with the selected tube current. When the actual and selected tube currents differed, the filament current was adjusted down or up from the value read from the curves as necessary to bring the actual and selected tube currents together.

One of the problems with this prior art calibration technique is that it could damage the x-ray tube filament. The filament has a low impedance and operates at a high current. Filament temperature varies generally with power across it, i.e. $I^2R$ where I is the filament current and R is the filament resistance and filament current varies generally as V/R, wh r V is th voltage applied across th filam nt. Even n rmal manufacturing tol rances f this filam nt can cause a major change in its resistance, hence its gen rating temperature and th resultant tube current. F r example, typical tolerances for the filament current n the curve table are of the rder of ± 0.15 amps, A variation of 0.15 amps can make a diff rence of plus or minus 300 to 400 mA in th tube current Particularly when testing the high tube curr nt values, the filament might produce up to 400 mA more than expected. This extra tube current increases the heating of the anode. A tube current increase of the 300 to 400 milliamp range can increase the anode temperature to the melting point or cause other thermal damage.

US-A-4930145 discloses a filament current regulator for an X-ray generator which includes a calibration circuit which compares the actual x-ray tube filament current to a predefined filament current reference value. Another circuit is included which compares the actual x-ray tube voltage, applied across the anode and to cathode of the tube, to a predefined reference voltage value. The regulator adjusts the filament current during a first time interval of an exposure based on only the filament current comparison, and during the remainder of the exposure based substantially on the excitation voltage comparison. The regulator apparatus also integrates the difference between the actual filament current and the reference current value over a given interval during the exposure. The integrated result is employed by the regulator to redefine the filament current reference value.

It is an object of this invention to provide a new and improved calibration procedure which avoids damage to the x-ray tube anode.

According to the invention there is provided a method of calibrating x-ray tube filament currents of an x-ray tube having an anode and a cathode filament, wherein said method comprises determining the filament current at the emission point by : a) applying a selected voltage across the cathode filament and the anode of the x-ray tube; b) applying a small current to the cathode filament of the x-ray tube at which no tube current flows; c) while the selected voltage is being applied, monitoring for tube current between the cathode filament and the anode; and d) increasing the cathode filament current and repeating steps a) - c) until tube current is monitored, the filament current at this point being designated as the filament current at the emission point.

Further, according to the invention there is provided an x-ray tube system comprising: an x-ray tube having an anode , a cathode filament, and a power supply means for selectively applying a voltage across the anode and cathode filament; x-ray tube voltage control means for selectively controlling the voltage applied across the anode and cathode filament; cathode filament current control means for controlling a current applied through the cathode filam nt; and tube curr nt monitoring m ans for monitoring a tub current flow b tween th cathode filam nt and th anode; charact rized in that calibration m ans are provided including: means arranged to cause th cathode filam nt current control means to

apply a small current t the cathod filament f the x-ray tube at which no tube current flows; means arranged t cause th x-ray tube voltage control means t apply a sel cted voltage across th cathode filament and the anode; means arranged to cause the tube current monitoring means to determine whether the x-ray tube current flows between the cathode filament and the anode while the preselected voltage is being applied; and means arranged to cause the cathode filament current control means to increase the cathode filament current until a tube current flows between the cathode filament and the anode.

One advantage of the present invention is that it avoids thermally damaging the x-ray tube.

Another advantage of the present invention resides in approaching each calibration current from below which reduces tube current overshoot.

Another advantage of the present invention is that it may quickly, in less than two minutes, automatically calibrate a full range of x-ray tube operating parameters.

One system and method in accordance with the invention will now be described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a diagrammatic illustration of an x-ray tube in combination with an automatic calibration and control circuit;

Figure 2 is illustrative of an exemplary tube current (mA), tube voltage (KV), and filament current ($I_{fil}$) relationship;

Figure 3 is a flow chart illustrating the steps or means for identifying the emission point, and,

Figure 4 illustrates appropriate steps or means for determining the filament current calibration at each of a plurality of tube current and voltage settings.

With reference to Figure 1, an x-ray tube 10 has an anode 12 and a cathode filament 14. A filament current control means 16 provides a selectably adjustable current through the cathode filament 14 causing the filament to boil off an electron cloud. A power supply 20 under the control of kV or tube voltage control means 22 applies a selected voltage between the cathode filament 14 and the anode 12. The potential difference causes a tube current 24 as the boiled off electrons are attracted from the cathode filament 14 to the surface of the anode 12. The collision of this high energy electron beam 24 with the anode causes a beam of x-rays 26 to be generated. However,the energy of the collision is so high that the anode 12 heats to near its melting point. The x-rays 26 trav rse a patient receiving region and impinge on an x-ray sensitive medium 28, such as photographic film, solid state x-ray detectors, r the like. Optionally, the anode 12 may rotate such that the l ctron b am 24 dwells a short r durati n at a giv n point on the anode surface t reduce heating and avoid thermal degradation.

The power supply 20 includes a high tension transformer 30 whose primary voltage is controlled by the tube v ltage control 22. A pair of s condary windings are each connected across analogous rectifier bridges 32, 34 such that the selected tube voltage is created across output terminals $36^+$ and $36^-$.

Because the current flow through the x-ray tube is essentially a closed loop, the same current that flows between the cathode and the anode flows through a resistor 40 connecting the rectifier bridges 32, 34. Accordingly, the x-ray current 24 can be sensed by sensing the voltage across the resistor 40. A voltage controlled oscillator 42 is connected across the resistor 40 such that it produces an output signal whose frequency or pulse rate varies in proportion to the voltage across resistor 40, hence the tube current 24. A counter means 44 counts the output pulses of the voltage controlled oscillator 42 for a unit time to provide a numeric output indicative of the actual tube current 24.

With continuing reference to FIGURE 1 and further reference to FIGURE 2, a microprocessor control circuit 50 instructs the filament current control 16 and the tube voltage control 22 in accordance with the actual tube current 24 as determined by the counter 44. At a selected tube voltage, generally the highest voltage rating, e.g. 120 kV, no tube current 24 flows when the filament current $I_{fil}$ is low , e.g. below 3.0 amps. As the filament current increases, no tube current will flow until an emission point 52 is reached, e.g. around 3.4 amps. Thereafter, each small increase in the filament amperage causes the tube current to change generally along a fixed voltage, mA v $I_{fil}$ curve 54. As the tube voltage is decreased towards the minimum tube voltages 56, e.g. 40 kV, a progressively higher filament current becomes necessary to reach the emission point, as described by curve 58. In this manner, the tube voltage, tube current, and filament current relationship is defined by a generally warped surface.

With continuing reference to Figure 2 and further reference to Figure 3, the microprocessor 50 has a means or performs a step 60 causing the filament current control means 16 to set the filament current to some initial low value, e.g. 3.0 amps. A step or means 62 causes the x-ray tube voltage control means 22 to apply the maximum selectable tube voltage across the cathode 14 and anode 12 to start an exposure. A tube current determining means or step 64 monitors the output of counter 44 to determine whether a tube current 24 is flowing. If there is no tube current flowing, a step or means 66 causes the filament current control means 16 to increase th filament current by a pr sel ct d increment. The tube voltag is applied again at 62 and a check is again made at 64 to determin whether the tub current 24 has started t fl w. This increm nt, exp se, and

check routine is continued cyclically until a tube current 24 is sensed.

Once the tub current 24 has started to flow, a step or means 70 divides the filament current increment by two to reduce the increment size. A step or means 72 causes the filament current control means 16 to decrease the filament current by the half size increment. A step or means 74 causes the voltage control means 22 to start another exposure so that a tube current monitoring step or means 76 can check whether the tube current 24 still flows at this lower filament current. If the tube current 24 is still flowing at this lower current, a filament current decreasing means or step 78 causes the filament current to be decreased by the currently set increment. If the tube current is no longer flowing at this filament current, a filament current increasing means or step 80 causes the filament current to be increased by the currently set half increment. An increment reducing means or step 82 divides the filament current increment in half again. Optionally, step or means 82 may be disposed between steps or means 74 and 76. This process of adjusting the filament current, starting an exposure to see if a tube current flows, and dividing the filament current increment by two continues until a step or means 84 determines that a preselected minimum filament current increment size has been reached. The filament current at this point is then designated as the filament current at the emission point 52.

With reference to Figure 4 and continuing reference to Figure 2, once the emission point 52 is determined, the filament current which causes a first selected tube current 90 to flow at maximum tube voltage is determined. A step or means 92 sets the filament current at the emission current level, i.e. at the filament current level which produces the smallest measurable tube current which is lower than the selected tube current 90. A tube current incrementing means or step 94 sets a desired tube current value successively to each of a plurality of preselected values and resets the tube voltage to the maximum voltage. An x-ray exposure starting step or means 96 causes the tube voltage control means 22 to apply the tube voltage across the anode 12 and cathode 14 and a tube current detecting means or step 98 determines whether the tube current measured by the counter means 44 exceeds the tube current selected with a tube current selecting step or means 94. If the actual tube current is below the selected tube current, a filament current incrementing step or means 100 increments the filament current by a preselected filament current increment and the exposure and comparing steps are repeated. This expose, compare and increm nt procedur is repeated until the actually m asured tub current xce ds the s lected tube current.

Once th tube curr nt xceeds th s lected tube current, a step or means 102 divides the filament current increment by tw t reduce the step r increment size. A step or means 104 causes the filament current control means 16 to d crease r decrement the filament curr nt by the half size increment. A step or means 106 caus s the voltage control means 22 to start another exposure so that a tube current monitoring step or means 108 can check whether the tube current still exceeds the selected tube current at this lower filament current. If the tube current still exceeds the selected tube current at this lower filament current, a filament current decreasing means or step 110 causes the filament current to be decreased by the currently set increment, and if the tube current is less than selected at this filament current, a filament current increasing means or step 112 causes the filament current to be increased by the currently set increment. An increment reducing step 114 divides the filament current step in half again. This process of adjusting the filament current, starting an exposure to see if the tube current exceeds the selected current, and dividing the filament increment by two continues until a step or means 116 determines that a preselected minimum filament current increment size has been reached. The filament current at this point is then designated as the calibrated filament current at the selected kV and mA.

When the minimum increment value determining step or means 116 determines that the best possible calibration has been attained, a recording means 118 records the filament current for the selected tube voltage and tube current combination in an appropriate memory cell 120 a filament current memory means 122 (Figure 1). A tube voltage decrementing means or step 124 decrements the tube voltage to a lower one of the selected tube voltages. The filament current is again incremented and zeroed in on the appropriate tube filament current value to attain the first selected tube current at this lower selected tube voltage. The filament current value is recorded in an appropriate memory cell 128 of the filament current memory means 122.

This process is repeated until a tube voltage minimum determining step or means 130 determines that the minimum selectable tube voltage has been reached. When the minimum tube voltage is reached, a step or means 132 resets the filament current to the previously calibrated filament current at the maximum kV, i.e. point 90. The tube current incrementing step or means 94 increments the tube current and resets the tube voltage value to the maximum value. Thus, the first exposure at this new mA-kV combination is guaranteed not to exceed the anode loading limit. The tube current calibration process is repeated until the appropriate filament current is determined to achi ve the next s lected calibration point 134 and ach of a selected plurality of successive tube voltage, tube current combinations ar obtain d.

Although every selectable tube current, tube voltage combination might be s lected and calibrated in-

dividually, it is preferred that nly a fraction of the tub current, tube v ltag combinations ar actually calibrated and that th rest ar determined by interpolation. T this end, an interpolating means or step 140 interpolates the actually calibrated tube currents (denoted by a solid circle in Figure 2 and an x in memory 122 of Figure 1) to determine appropriate tube currents for each selectable tube current, tube voltage combination.

It is to be appreciated that once the emission current level is determined, the selected tube current, tube voltage combinations can be calibrated in various orders. Preferably, the calibration is conducted from the minimum tube current towards the maximum tube current.

Once the current filament memory 122 has been filled, the x-ray tube is calibrated and ready to be operated. An operator keyboard 142 has appropriate input buttons or dials for the operator to select any one of the selectable x-ray tube voltage and current combinations. The microprocessor means 50 addresses the current filament memory 122 with the selected tube voltage and current and retrieves the corresponding filament current. The microprocessor then controls the current filament control means 16 to provide the retrieved filament current and controls the tube voltage control means 22 to provide the selected tube voltage for a selected exposure duration.

## Claims

1. A method of calibrating x-ray tube filament currents of an x-ray tube (10) having an anode (12) and a cathode filament (14), wherein said method comprises, as a first step, determining the filament current at the emission point (52) by : a) applying a selected voltage across the cathoder filament (14) and the anode (12) of the x-ray tube (10); b) applying a small current to the cathode filament (14) of the x-ray tube (10) at which no tube current flows; c) while the selected voltage is being applied, monitoring for tube current between the cathode filament (14) and the anode (12); and d) increasing the cathode filament current and repeating steps a) - c) until tube current is monitored, the filament current at this point being designated as the filament current at the emission point (52).

2. A method of calibrating x-ray tube filament currents according to Claim 1, characterised in that it further comprises the steps of: e) applying a first sel cted tube voltag which is lower than or quals the selected voltage applied in st p b); f) incr asing the filament current ($I_{fil}$) from the filament current value at which the filament emission point (52) was monit red; g) monitoring the r sultant tube current; $h_1$) comparing the monitored tube current with a presel cted tube current; and, $h_2$) repeating st ps f) - h) until the selected tube current is reached.

3. A method as claimed in Claim 2 further including the step of: i) storing the filament current at which the preselected tube current is reached in a filament current memory means (122) in a memory cell (120) that is addressable by the selected tube voltage and tube current pair which defines a tube current/tube voltage calibration for the x-ray tube.

4. A method as claimed in Claim 3 further including the step of: j) decrementing the first selected tube voltage to a lower selected tube voltage and repeating steps f) - i), wherein, in step f), the filament current ($I_{fil}$) is increased from the previously calibrated filament current instead of from the filament current value at which the filament emission point (52) was monitored.

5. A method as claimed in Claim 4 further including the step of: k) incrementing the preselected tube current and repeating steps e) - j), whereby anode overloading is avoided by basing each of a plurality of tube current/tube voltage calibrations on the previously calibrated tube current/tube voltage values.

6. A method as claimed in Claim 3 further including incrementing the preselected tube current and repeating steps f) to i).

7. A method as claimed in any preceding claim wherein the step of increasing the filament current includes changing the filament current in increments of a first magnitude.

8. A method as claimed in Claim 7 further including the step of decrementing the filament current by an increment of half said first magnitude, after the filament emission point is first monitored and repeating step c); if the tube current is still detected, decrementing the filament current by an increment of a quarter of said first magnitude and if the tube current is no longer detected, incrementing the tube current by the increment of a quarter of said first magnitude, and repeating step c).

9. A method as claimed in Claim 7 when dependent on any f Claims 2 t 6 further including: after the tub curr nt xceeds th pres lected tube curr nt, d crementing the filament current by an increment f half said first magnitud and repeating st ps g) and h); if the tub current still x-

ceeds th preselect d tube current, d crementing the filam nt curr nt by an increment of a quart r of said first magnitude and if the tube current is below the preselected tube current, incrementing the tube current by an increment of a quarter of said first magnitude and repeating steps g) and h).

10. A method of calibrating pairs of x-ray tube filament current and tube voltage values, which comprises the steps of applying a filament current and tube voltage at a first previously calibrated pair of values to an x-ray tube (10), said calibrated pair being determined by the method according to Claim 2; setting the tube voltage to a second selected value; progressively increasing the filament current until a tube current reaches a second selected value; recording the filament current at which the tube current reaches the second selected value and recording the tube voltage/tube current values; repeating the progressively increasing steps for each of a plurality of filament current and voltage pairs, whereby anode overloading is prevented by basing each calibration on previously calibrated values.

11. An x-ray tube system comprising: an x-ray tube (10) having an anode (12), a cathode filament (14), and a power supply means (20) for selectively applying a voltage across the anode (12) and cathode filament (14); x-ray tube voltage control means (22) for selectively controlling the voltage applied across the anode (12) and cathode filament (14); cathode filament current control means (16) for controlling a current applied through the cathode filament; and tube current monitoring means (64) for monitoring a tube current flow (24) between the cathode filament and the anode, characterized in that calibration means are provided including: means (50) arranged to cause the cathode filament current control means to apply a small current to the cathode filament of the x-ray tube at which no tube current flows; means (50) arranged to cause the x-ray tube voltage control means to apply a selected voltage across the cathode filament and the anode; means arranged to cause the tube current monitoring means (64) to determine whether the x-ray tube current (24) flows between the cathode filament and the anode while the preselected voltage is being applied; and means (66) arranged to cause the cathode filament current control means to increase the cathode filam nt current until a tub current fl ws betw n th cathod filam nt and the anode.

12. An x-ray tub system as claimed in Claim 11 wherein the calibration means further includes: means (98) for comparing the monit r d tube curr nt with a presel ct d tub current.

13. An x-ray tub system as claimed in Claim 11 r 12 further including: filament current memory means (122) for storing each filament current at which a selected tube current is monitored, the filament current memory means being addressable by each of a plurality of preselected tube voltage and tube current values.

14. An x-ray tube system as claimed in Claims 11, 12 or 13 wherein the means (66) arranged to cause the cathode filament current control means (16) to increase the filament current increases the filament current in preselected current increments and wherein the calibration means further includes: means (78) for decreasing the filament current in the preselected current increments, and means (70, 82) for reducing the preselected current increments.

**Patentansprüche**

1. Verfahren zum Kalibrieren von Röntgenröhrenheizströmen einer Röntgenröhre (10), die eine Anode (12) und einen Kathodenheizfaden (14) aufweist, wobei das Verfahren als einen ersten Schritt die Ermittlung des Heizstroms am Emissionspunkt (52) umfaßt durch: (a) Anlegen einer selektierten Spannung über den Kathodenheizfaden (14) und die Anode (12) der Röntgenröhre (10); (b) Einspeisen eines geringen Stroms in den Kathodenheizfaden (14) der Röntgenröhre (10), wobei bei diesem Strom kein Röhrenstrom fließt; (c) Verfolgen des Röhrenstroms zwischen dem Kathodenheizfaden (14) und der Anode (12), während die selektierte Spannung angelegt ist; und (d) Erhöhen des Kathodenheizstroms und Wiederholen der Schritte (a) bis (c), bis ein Röhrenstrom aufgenommen ist, wobei der Heizstrom an diesem Punkt als der Heizstrom am Emissionspunkt (52) designiert wird.

2. Verfahren zum Kalibrieren von Röntgenröhrenheizströmen gemäß Anspruch 1,
**dadurch gekennzeichnet**, daß es ferner die Schritte umfaßt: (e) Anlegen einer ersten selektierten Röhrenspannung, die geringer oder gleich der selektierten im Schritt (b) angelegten Spannung ist; (f) Erhöhen des Heizstroms ($I_{fil}$) vom Heizstromwert, bei dem der Heizstromemissionspunkt (52) aufg nommen wurde; (g) Verfolgen des resultierenden Röhrenstroms; ($h_1$) V rgleichen des aufgenommenen Röhrenstroms mit ein m v rselektiert n Röhrenstrom; und ($h_2$) Wied rh len der Schritte (f) bis (h), bis der selek-

tiert Röhrenstrom rreicht ist.

3. Verfahren nach Anspruch 2, ferner umfassend den Schritt: (i) Speichern des Heizstroms, bei dem der vorselektierte Röhrenstrom erreicht ist, in einer Heizstromspeichereinrichtung (122) in einer Speicherzelle (120), die durch das selektierte Röhrenspannungs- und Röhrenstrompaar adressierbar ist, welches eine Röhrenstrom/Röhrenspannungs-Kalibrierung für die Röntgenröhre definiert.

4. Verfahren nach Anspruch 3, ferner umfassend den Schritt: (j) schrittweises Verringern der ersten selektierten Röhrenspannung auf eine niedrigere selektierte Röhrenspannung und Wiederholen der Schritte (f) bis (i), wobei in Schritt (f) der Heizstrom ($I_{fil}$) statt vom Heizstromwert, bei dem der Heizstromemissionspunkt (52) aufgenommen wurde, vom zuvor kalibrierten Heizstrom erhöht wird.

5. Verfahren nach Anspruch 4, ferner umfassend den Schritt: (k) Inkrementieren des vorselektierten Röhrenstroms und Wiederholen der Schritte (e) bis (j), wobei eine Anodenüberlastung vermieden wird, indem jede einer Mehrzahl von Röhrenstrom/Röhrenspannungs/Kalibrationen auf der Grundlage der zuvor kalibrierten Röhrenstrom/Röhrenspannungs-Werte ermittelt wird.

6. Verfahren nach Anspruch 3, ferner umfassend das Inkrementieren des vorselektierten Röhrenstroms und das Wiederholen der Schritte (f) bis (i).

7. Verfahren nach einem vorhergehenden Anspruch, in welchem der Schritt der Erhöhung des Heizstroms die Änderung des Heizstroms in Inkrementen einer ersten Größe umfaßt.

8. Verfahren nach Anspruch 7, ferner umfassend den Schritt der schrittweisen Absenkung des Heizstroms um ein Inkrement der Hälfte dieser ersten Größe, nachdem der Heizstromemissionspunkt zuerst aufgenommen wurde, und der Wiederholung des Schritts (c); des schrittweisen Absenkens des Heizstroms um ein Inkrement eines Viertels der ersten Größe, falls der Röhrenstrom noch detektiert wird, und falls der Röhrenstrom nicht länger detektiert wird, des Inkrementierens des Röhrenstroms un das Inkrement eines Viertels der ersten Größe, und Wiederholen d s Schritts (c).

9. Verfahren nach Anspruch 7 bei Rückbeziehung auf inen der Ansprüche 2 bis 6, ferner umfassend: schrittweises Absenk n des Heizstroms um in Inkrement iner Hälfte der ersten Größe und Wiederholen der Schritte (g) und (h), nachd m der Röhr nstrom den vorselektierten Röhr nstrom überschritten hat; falls der Röhrenstrom den vorselektierten Röhrenstrom immer noch übersteigt, des schrittweisen Absenkens des Heizstroms um ein Inkrement eines Viertels der ersten Größe, und falls der Röhrenstrom unter dem vorselektierten Röhrenstrom liegt, das Inkrementieren des Röhrenstroms um ein Inkrement eines Viertels der ersten Größe und Wiederholen der Schritte (g) und (h).

10. Verfahren zum Kalibrieren von Paaren aus Röntgenröhrenheizstrom- und Röhrenspannungswerten, welches Verfahren umfaßt die Schritte des Einspeisens eines Heizstroms und Anlegens einer Röhrenspannung aus einem ersten zuvor kalibrierten Wertepaar in bzw. an eine Röntgenröhre (10), wobei das kalibrierte Paar durch das Verfahren gemäß Anspruch 2 ermittelt wird; Einstellen der Röhrenspannung auf einen zweiten selektierten Wert; fortschreitendes Erhöhen des Heizstroms, bis ein Röhrenstrom einen zweiten selektierten Wert erreicht; Aufzeichnen des Heizstroms, bei dem der Röhrenstrom den zweiten selektierten Wert erreicht, und Aufzeichnen der Röhrenspannungs/Röhrenstrom-Werte; Wiederholen der fortschreitend steigernden Schritte für jedes einer Mehrzahl von Heizstrom- und Spannungspaaren, wodurch eine Anodenüberlastung verhindert wird, indem jede Kalibration auf der Grundlage der zuvor kalibrierten Werte ermittelt wird.

11. Röntgenröhrenvorrichtung, aufweisend: eine Röntgenröhre (10), die eine Anode (12), einen Kathodenheizfaden (14) und eine Versorgungseinrichtung (20) aufweist, die selektiv eine Spannung über die Anode (12) und den Kathodenheizfaden (14) legt; eine Röntgenröhrenspannungssteuereinrichtung (22) zur selektiven Steuerung der über die Anode (12) und den Kathodenheizfaden (14) angelegten Spannung; eine Kathodenheizstromsteuereinrichtung (16) zum Steuern eines durch den Kathodenheizfaden zugeführten Stroms; und eine Röhrenstromverfolgungseinrichtung (64) zum Verfolgen eines Röhrenstromflusses (24) zwischen dem Kathodenheizfaden und der Anode,
**dadurch gekennzeichnet,**
daß Kalibriereinrichtungen vorgesehen sind, die aufweisen: eine Einrichtung (50), die dazu ausgelegt ist, di Kathod nh izstromsteu reinrichtung dazu zu v ranlass n, ein n geringen Strom in den Kathodenheizfaden der Röntg nröhre einzuspeis n, bei dem k in Röhrenstrom fließt, ine Einrichtung (50), die dazu ausgel gt ist, die Rönt-

genröhrenspannungsspannungssteuereinricht ung dazu zu veranlassen, eine sel ktierte Spannung über den Kathodenheizfaden und die Anode zu legen; ein Einrichtung, di dazu ausgelegt ist, die Röhrenstromverfolgungseinrichtung (64) dazu zu veranlassen, zu ermitteln, ob der Röntgenröhrenstrom (24) zwischen dem Kathodenheizfaden und der Anode fließt, während die vorselektierte Spannung angelegt ist; und eine Einrichtung (66), die dazu ausgelegt ist, die Kathodenheizstromsteuereinrichtung dazu zu veranlassen, den Kathodenheizstrom zu steigern, bis ein Röhrenstrom zwischen dem Kathodenheizfaden und der Anode fließt.

12. Röntgenröhrenvorrichtung nach Anspruch 11, in welcher die Kalibrierungseinrichtungen ferner aufweisen, eine Einrichtung (98) zum Vergleichen des aufgenommenen Röhrenstroms mit einem vorselektierten Röhrenstrom.

13. Röntgenröhrenvorrichtung nach Anspruch 11 oder 12, ferner aufweisend: eine Heizstromspeichereinrichtung (122) zum Speichern jedes Heizstroms, bei dem ein selektierter Röhrenstrom aufgenommen wird, wobei die Heizstromspeichereinrichtung durch jeden einer Mehrzahl von selektierten Röhrenspannungs- und Röhrenstromwerten adressierbar ist.

14. Röntgenröhrenvorrichtung nach Anspruch 11, 12 oder 13, in welcher die Einrichtung (66) dazu ausgelegt ist, die Kathodenheizstromsteuereinrichtung (16) dazu zu veranlassen, die Heizstromzunahmen des Heizstroms in vorselektierten Strominkrementen zu steigern, und in welcher die Kalibrierungseinrichtungen ferner aufweisen: eine Einrichtung (78) zur Absenkung des Heizstroms in vorselektierten Strominkrementen, und Einrichtungen (70, 82) zum Reduzieren der vorselektierten Strominkremente.

## Revendications

1. Procédé d'étalonnage des courants de filament d'un tube radiographique (10) ayant une anode (12) et un filament cathodique (14), le procédé comprenant, dans une première étape, la détermination du courant de filament au point d'émission (52) par : a) application d'une tension choisie entre le filament cathodique (14) et l'anode (12) du tube radiographique (10), b) application d'un p tit courant au filam nt cathodique (14) du tube radiographique (10) pour lequ l aucun courant ne circule dans le tube, c) pendant qu la tensi n choisi est appliquée, contrôl du courant du tube entre le filament cathodique (14) et l'anode (12), t d) augmentation du courant du filament cathodiqu et répétition des étapes a) à c) jusqu'à ce que le courant du tube soit contrôlé, le courant du filament à ce moment étant appelé "courant du filament au point d'émission" (52).

2. Procédé d'étalonnage des courants de filament d'un tube radiographique selon la revendication 1, caractérisé en ce qu'il comprend en outre les étapes suivantes : e) l'application d'une première tension choisie de tube qui est inférieure ou égale à la tension choisie appliquée dans l'étape b), f) l'augmentation du courant de filament ($I_{fil}$) depuis la valeur du courant de filament pour laquelle le point d'émission du filament (52) a été contrôlé, g) le contrôle du courant résultant du tube, $h_1$) la comparaison du courant contrôlé du tube à un courant préréglé du tube, et $h_2$) la répétition des étapes f)-h) jusqu'à ce que le courant choisi du tube soit atteint.

3. Procédé selon la revendication 2, comprenant en outre l'étape i) de mémorisation du courant du filament pour lequel le courant prédéterminé du tube est atteint dans une mémoire (122) de courant de filament, dans une cellule (120) de la mémoire qui peut être adressée à l'aide de la paire choisie formée de la tension du tube et du courant du tube qui détermine un étalonnage courant-tension de tube pour le tube radiographique.

4. Procédé selon la revendication 3, comprenant en outre l'étape g) de diminution de la première tension choisie du tube à une plus faible tension choisie de tube et de répétition des étapes f) à i), et dans laquelle, dans l'étape f), le courant du filament ($I_{fil}$) est augmenté du courant de filament antérieurement étalonné à la place de la valeur du courant de filament à laquelle le point d'émission du filament (52) a été contrôlé.

5. Procédé selon la revendication 4, comprenant en outre l'étape k) d'augmentation du courant préréglé du tube et de répétition des étapes e) à j), si bien que la surcharge de l'anode est évitée par détermination de chacun des étalonnages courant-tension de tube d'après les valeurs courant-tension de tube étalonnées antérieurement.

6. Procédé selon la revendication 3, comprenant en outre l'augmentation du courant préréglé du tube et la répétition des étapes f) à l).

7. Procédé s lon l'un quelconqu d s rev ndications précéd ntes, dans l quel l'étape d'augm ntati n du courant du filament compr nd le changement du courant du filament par pas élém ntaires ayant un première amplitude.

8. Procédé sel n la revendicati n 7, compr nant en utre l'étap de réduction du courant du filament d'un pas élémentaire égal à la moitié d la première amplitude, après que le point d'émission du filament a été contrôlé la première fois, et de répétition de l'étape c), et, si le courant du tube est encore détecté, de réduction du courant du filament d'une valeur élémentaire égale au quart de la première amplitude et, si le courant du tube n'est plus détecté, d'augmentation du courant du tube de la valeur élémentaire égale au quart de la première amplitude, et de répétition de l'étape c).

9. Procédé selon la revendication 7 lorsqu'elle dépend de l'une quelconque des revendications 2 à 6, comprenant en outre, après que le courant du tube a dépassé le courant préréglé du tube, la réduction du courant du filament d'une valeur élémentaire égale à la moitié de la première amplitude et la répétition des étapes g) et h), si le courant du tube dépasse encore le courant préréglé du tube, la réduction du courant du filament d'une quantité élémentaire égale au quart de la première amplitude et, si le courant du tube est inférieur au courant préréglé du tube, l'augmentation du courant du tube d'une valeur élémentaire égale au quart de la première amplitude et la répétition des étapes g) et h).

10. Procédé d'étalonnage de paires de valeurs de courant de filament et de tension de tube radiographique, qui comprend les étapes suivantes : l'application d'un courant de filament et d'une tension de tube, ayant une première paire de valeurs préalablement étalonnée, à un tube radiographique (10), la paire étalonnée étant déterminée par le procédé selon la revendication 2, le réglage de la tension du tube à une seconde valeur choisie, l'augmentation progressive du courant du filament jusqu'à ce que le courant du tube atteigne une seconde valeur choisie, l'enregistrement du courant du filament pour lequel le courant du tube atteint la seconde valeur choisie, et l'enregistrement des valeurs de la tension et du courant du tube, puis la répétition des étapes d'augmentation progressive pour chacune de plusieurs paires de valeurs du courant du filament et de la tension, si bien que la surcharge anodique est évitée par détermination de chaque étalonnage d'après les valeurs étalonnées antérieurement.

11. Ens mble à tube radiographique comprenant un tub radiographique (10) ayant un anod (12), un filament cathodique (14), et une alim ntation (20) destinée à appliqu r sél ctiv ment une t nsion entre l'anode (12) et le filament cath dique (14), un dispositif (22) de réglage sélectif de la tension appliquée entre l'an de (12) et le filament cathodiqu (14), un dispositif (16) de réglage d'un c urant appliqué au filam nt cathodique, et un dispositif (64) de contrôle du courant dans le tube destiné à contrôler la circulation d'un courant (24) dans le tube entre le filament cathodique et l'anode, caractérisé en ce qu'il comprend un dispositif d'étalonnage qui comporte un dispositif (50) destiné à provoquer l'application, par le dispositif de réglage du courant du filament cathodique, d'un petit courant appliqué au filament cathodique du tube radiographique et pour lequel aucun courant ne circule dans le tube, un dispositif (50) destiné à provoquer l'application, par le dispositif de réglage de la tension du tube radiographique, d'une tension choisie entre le filament cathodique et l'anode, un dispositif destiné à provoquer la détermination, par le dispositif (64) de contrôle du courant du tube, du fait que le courant (24) du tube radiographique circule entre le filament cathodique et l'anode lorsque la tension préréglée est appliquée, et un dispositif (66) destiné à provoquer l'augmentation, par le dispositif de réglage du courant du filament cathodique, du courant du filament cathodique jusqu'à ce qu'un courant du tube circule entre le filament cathodique et l'anode.

12. Ensemble à tube radiographique selon la revendication 11, dans lequel le dispositif d'étalonnage comporte en outre un dispositif (98) de comparaison du courant contrôlé du tube à un courant préréglé du tube.

13. Ensemble à tube radiographique selon la revendication 11 ou 12, comprenant en outre une mémoire (122) de courant de filament destinée à mémoriser chaque courant de filament pour lequel un courant choisi du tube est contrôlé, la mémoire de courant de filament pouvant être adressée par chaque ensemble de plusieurs valeurs prédéterminées de la tension du tube et du courant du tube.

14. Ensemble à tube radiographique selon la revendication 11, 12 ou 13, dans lequel le dispositif (66) destiné à provoquer l'augmentation, par le dispositif (16) de réglage du courant de filament cathodique, du courant du filament augmente le courant du filament par quantités élémentaires préréglées du courant, et le dispositif d'étalonnage comporte en outre un dispositif (78) destiné à réduire l courant du filament par quantités élémentaires préréglées du courant, et un dispositif (70, 82) destiné à réduire les quantités élémentair s préréglées du courant.

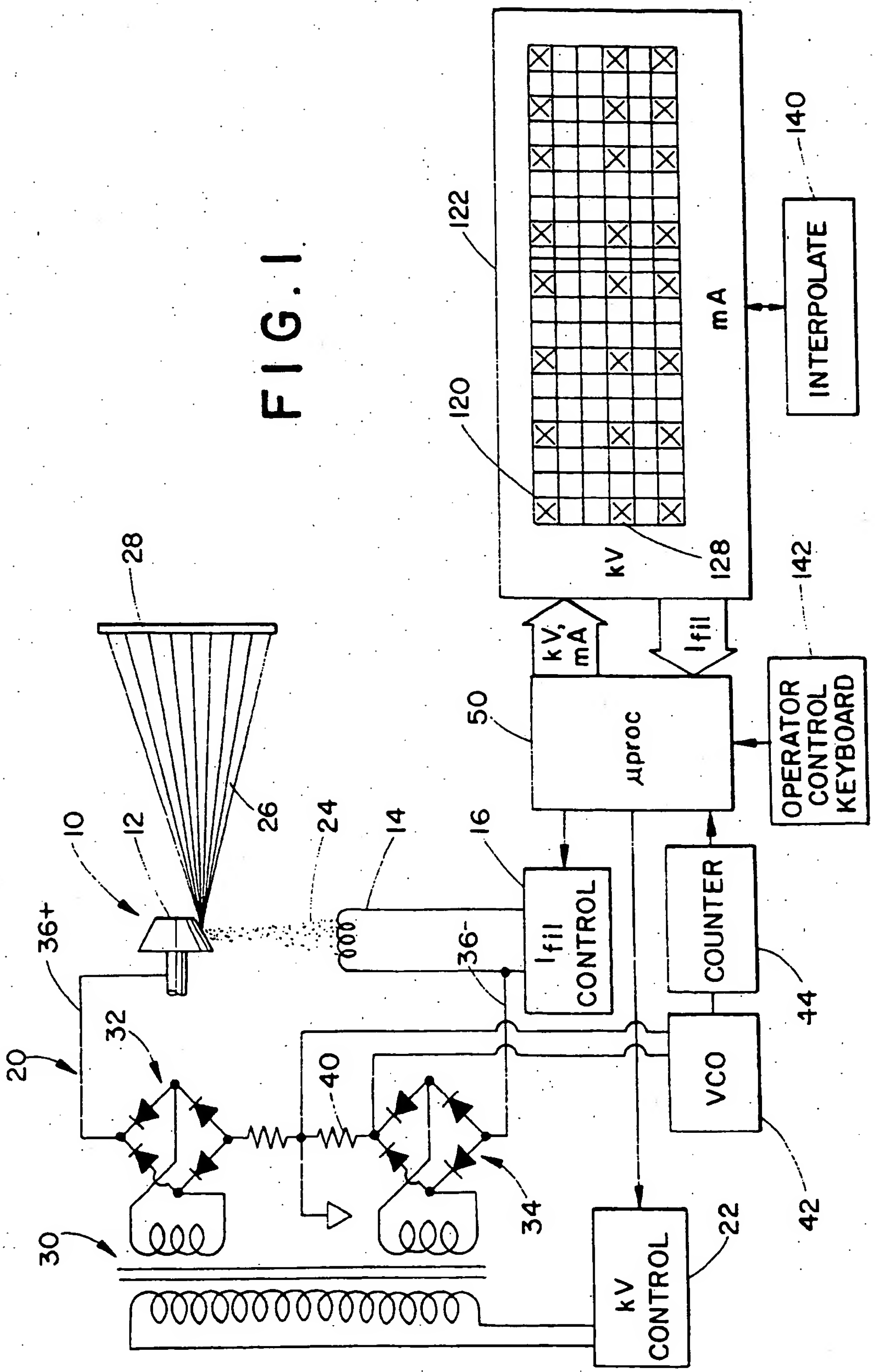

10
12
36+
20
32
40
30
34
36-
14
24
26
28
16
$I_{fil}$ CONTROL
50
μproc
kV; mA
$I_{fil}$
122
120
128
kV
mA
140
INTERPOLATE
142
OPERATOR CONTROL KEYBOARD
COUNTER
44
VCO
42
kV CONTROL
22

FIG. 1

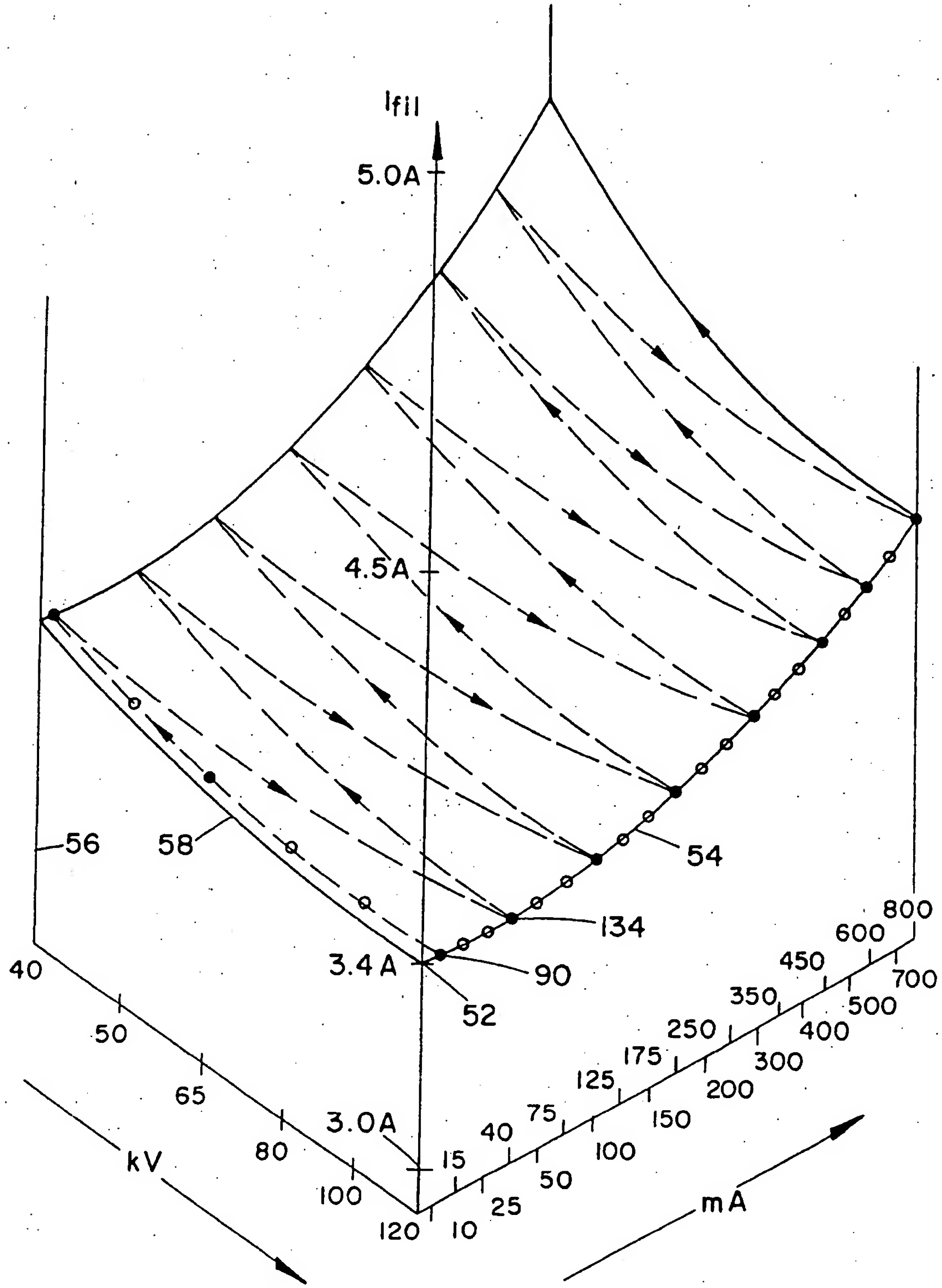

Ifil
5.0A
4.5A
3.4A
3.0A
56
58
54
134
90
52
40
50
65
80
100
120
kV
15
10
40
25
75
50
125
100
175
150
250
200
350
300
450
400
600
500
800
700
mA

FIG.2

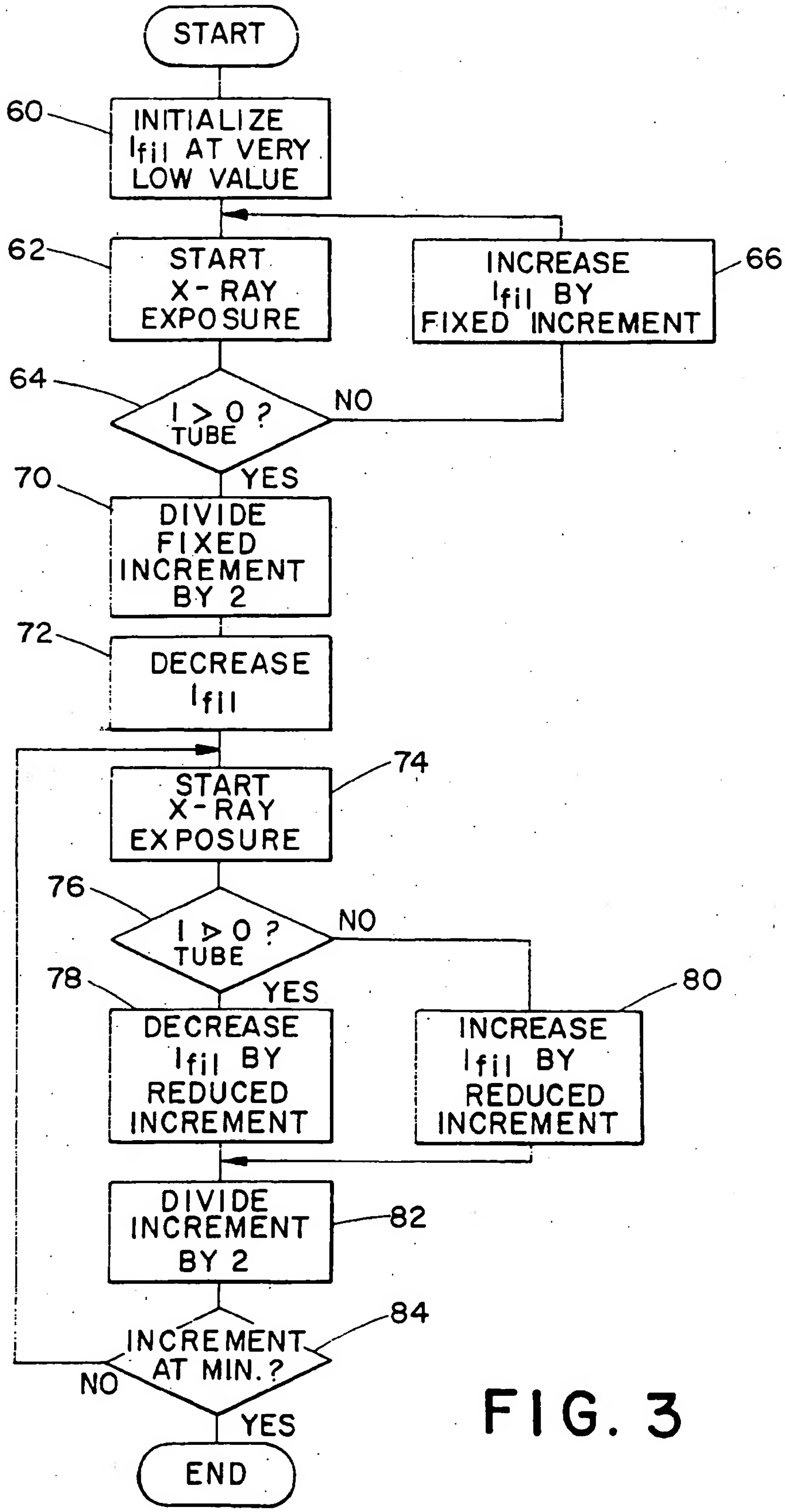
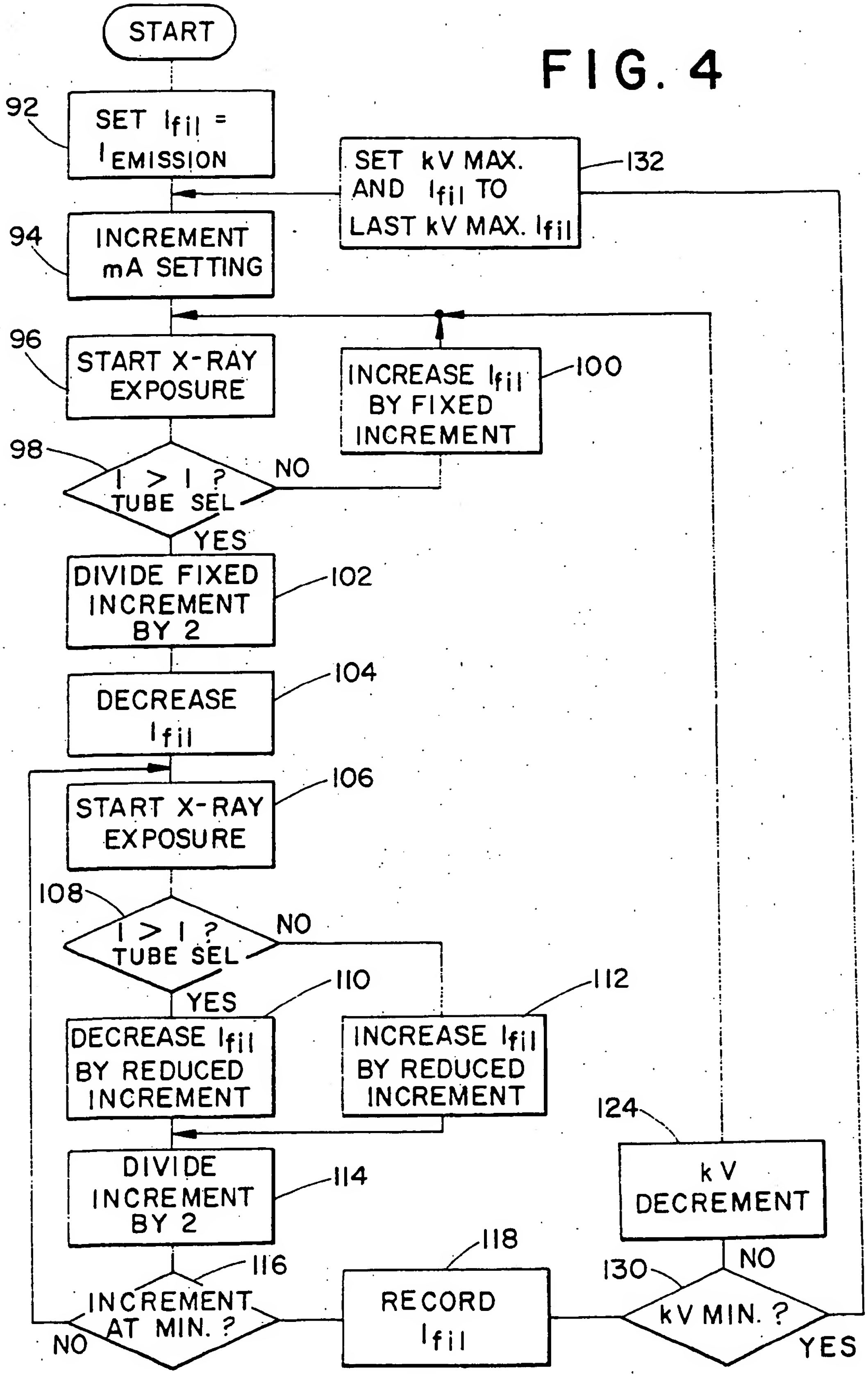

START
60
INITIALIZE
$I_{fil}$ AT VERY
LOW VALUE
62
START
X-RAY
EXPOSURE
INCREASE
$I_{fil}$ BY
FIXED INCREMENT
66
64
$I_{TUBE} > 0$ ?
NO
YES
70
DIVIDE
FIXED
INCREMENT
BY 2
72
DECREASE
$I_{fil}$
START
X-RAY
EXPOSURE
74
76
$I_{TUBE} > 0$ ?
NO
YES
78
DECREASE
$I_{fil}$ BY
REDUCED
INCREMENT
80
INCREASE
$I_{fil}$ BY
REDUCED
INCREMENT
DIVIDE
INCREMENT
BY 2
82
84
INCREMENT
AT MIN. ?
NO
YES
END

FIG. 3

FIG. 4


START
92
SET $I_{fil}$ = $I_{EMISSION}$
94
INCREMENT mA SETTING
96
START X-RAY EXPOSURE
98
$I_{TUBE} > I_{SEL}$ ?
NO
YES
INCREASE $I_{fil}$ BY FIXED INCREMENT
100
DIVIDE FIXED INCREMENT BY 2
102
DECREASE $I_{fil}$
104
START X-RAY EXPOSURE
106
108
$I_{TUBE} > I_{SEL}$ ?
NO
YES
110
DECREASE $I_{fil}$ BY REDUCED INCREMENT
112
INCREASE $I_{fil}$ BY REDUCED INCREMENT
DIVIDE INCREMENT BY 2
114
116
INCREMENT AT MIN. ?
NO
RECORD $I_{fil}$
118
130
kV MIN. ?
NO
YES
kV DECREMENT
124
SET kV MAX. AND $I_{fil}$ TO LAST kV MAX. $I_{fil}$
132